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PERFORMANCE OF A NEW VACUUM PACKAGE TO REDUCE TRITIUM CONTAMINATION FOR A 150 KILOVOLT NEUTRON GENERATOR

by Robert Steinberg and Donald L. Alger
Lewis Research Center
Cleveland, Ohio

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Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

ABSTRACT

A new vacuum package incorporating a titanium bulk sublimator/ion pump combination has been designed, built, and installed on a typical 150 kilovolt neutron generator. The sublimator/ion pump system provides the following operating advantages: (1) most of the tritium released from the target during deuteron bombardment is permanently buried in the sublimator chamber walls as titanium tritide; (2) a routine pump-down time of 30 minutes from atmosphere to 10^{-7} torr is obtained; (3) the vacuum system is able to handle large active gas loads because of its high pumping capacity; (4) neutron generator operating pressure may be varied between 10^{-7} torr and 10^{-5} torr by adjusting rate of sublimation.

INTRODUCTION

The incorporation of a titanium bulk sublimator in combination with an ion pump in a small accelerator vacuum system can reduce the tritium hazard associated with accelerator maintenance and operation, provide major advantages in pumping performance and improve system reliability. This vacuum concept was originally developed for a 300 kilovolt, 15 milliampere positive ion accelerator designed primarily for the production of neutrons[1]. Because both high gas loads and tritium targets were involved, high pumping speed capability and minimum maintenance were prime requirements for the vacuum system of the high current accelerator. As a direct result of the successful demonstration of sublimation/ion pumping in the 300 kilovolt machine, and because of the interest expressed by many people in seeing this technique adapted to a low current generator, the Lewis Research Center in cooperation with the Food and Drug Administration's Bureau of Radiological Health decided to demonstrate the basic advantages of this type of vacuum system when applied to a typical 150 kilovolt generator of the type found in many research and production facilities. This report describes the results of the first phase of this program.

The requirement for a high neutron yield has led many investigators to use the T(d,n) He^4 reaction to produce fast neutrons. Because tritium decays by beta emission, with a half-life of over 12 years, neutron generator system contamination can prove to be both a biological hazard and a maintenance nuisance requiring strict handling procedures.

Several pump configurations were considered for generator use before a satisfactory system was evolved. The use of an oil diffusion pump introduced the possibilities of hydrocarbon contamination of the tritium target, low pumping speed to volume ratio, possible tritium contamination of the oil and the necessity of a cryo-baffle. A getter-ion pump posed the problems of thermal instability[2] which results from re-emission of absorbed deuterium or tritium, repair problems because of tritium contamination[3] and reduced lifetime because of high deuterium gas-load requirements. These known pump difficulties combined with the fact that higher beam currents would only aggrevate the problems already present, led to the choice of separation of the pumping functions. Namely, the use of a small ion pump to handle the inert gases and hydrocarbons which result from normal outgassing and a titanium bulk sublimator to pump the large active gas load during generator operation and pumpdown from atmosphere.

Vacuum System for 150 Kilovolt Neutron Generator

A 150 kilovolt neutron generator of the type widely used in research and shown in figure 1 was modified by removing the 140 liter/sec ion pump and replacing it with a sublimation/ion pump vacuum system as shown in figure 2. With the exception of the addition of a double gate valve to allow changing the target without loss of generator vacuum, the physical size of the new system is about the same as the one it replaced. The generator ion beam passes through the sublimator chamber on the way to the target. Operation of the sublimator while the beam is on does not effect generator performance in any way. Two liquid nitrogen cooled sorption type pumps are used in place of a mechanical roughing pump. The use of these sorption pumps allow controlled venting of any tritium desorbed from the generator vacuum surfaces during pumpdown from atmosphere. Figure 3 shows a close-up view of the water cooled sublimator chamber with the sublimator mounted on the bottom and the small 11 liter/second high throughput water-cooled ion pump.

Sublimation Pumping

A comprehensive preliminary evaluation was conducted to determine which of several types of sublimation pumps would be most advantageous for neutron generator operation. A wire fed and a rod type, both depending on electron bombardment for heating, as well as resistance heated sublimator, were investigated. The acceptance criteria were high reliability, high pressure start capability, ease of operation and high titanium capacity. The unit found most acceptable and commercially available consists of a hollow sphere of titanium with an internal resistance heated element.[4] The head of the unit containing the sphere is shown in figure 4. The heating element radiates up to 750 watts of power to the sphere causing the outer surface to sublime on to the surrounding water-cooled substrate. The sphere contains 35 grams of usable titanium and the sublimation rate is variable from 0.01 to 0.5 grams/hour. Figure 5 shows a view thru a side port of the hollow sphere at operating temperature ($\sim$1500°C) and subliming at 0.5 grams/hour. The sublimed titanium combines with the active gases to form stable solid compounds on the sublimator chamber walls. In this way the sublimator pumps the high gas loads during pumpdown from 10^{-3} torr and during accelerator operation.

The hydrocarbons and inert gas load is pumped by an 11 liter/second high-throughput water-cooled ion pump.

Operating Characteristics

Figure 6 shows a typical pumpdown cycle for the neutron generator using two sorption pumps and the sublimator/ion pump system. It is routine to go from atmosphere to 8×10^{-7} torr in 30 minutes or less. One sorption pump takes the system from atmosphere to about 1×10^{-3} torr. The first sorption pump is closed after about 4 minutes. The second sorption pump is then opened and the sublimator turned on (the sublimator can be turned on up to 2×10^{-2} torr). After some initial outgassing of the sublimator and when the pressure decreases to between 5×10^{-4} and 2×10^{-4} torr, the second sorption pump is closed and the ion pump is turned on.

Figure 7a shows a typical pumpdown and operating cycle for the neutron generator with the sublimator operating in a batch mode (depositing a layer of titanium for 2 hours and then admitting gas). Figure 7b shows a similar cycle except that the sublimator is operating continuously (continuous mode) while a beam of deuterons is on target. The operating characteristics shown were obtained for several sublimation rates of 0.075, 0.10 and 0.5 grams/hour while operating at 120 kilovolts and 0.5 milliamperes.

Target Released Tritium

Most of the tritium released from the target is buried in the walls of the sublimator as titanium tritide and unlike an ion pump there is no problem with desorption of the tritium from the water-cooled pumping surfaces.

The sublimator chamber acts as an active gas trap and should extend considerably the life of the 11 liter/second ion pump. However, it can be expected that in time continuous pumping of tritium and deuterium will reduce its pumping speed. If the ion pump should become saturated, it is a simple matter to remove the magnet and clamp two heaters to the sides and bake out the ion pump into the operating sublimator. This virtually eliminates the problem of ion pump replacement and does away with the need for external pumping (which means further tritium contamination).

Sublimator Operating Mode and Lifetime

The sublimator chamber is a cylinder approximately 35 cm in length by 35 cm in diameter with a surface of about 4,000 cm^2 available for sublimation. At a sublimation rate of 0.5 grams/hour a pumping speed in excess of 10,000 liters/second is available at 10^{-6} torr.

After the present vacuum system was placed in operation a small air leak was discovered in the acceleration section. After several fruitless attempts to seal it and because we could maintain a reasonable vacuum with the leak, it was decided to complete the testing. The results presented in figure 6 and 7 were obtained with the leak present.

At a sublimation rate of 0.075 grams/hour we deposit about 2.6×10^{17} atoms of titanium/second. The ion source requires 5 atm-cm^3/hr, or about 7.4×10^{16} atoms/second. If we assume TiD_1 is formed then our leak must be of the order of 17 atm-cm^3/hr. Based on a leak rate of 17 atm-cm^3/hr a titanium sphere should last for over 450 hours of accelerator operation at 120 kilovolts and 0.5 milliamperes before replacement is required. If we consider a leak rate of 5 atm-cm^3/hr which is what may be expected under normal operating conditions, the titanium sphere should last for over 1,000 hours. The sublimator need only be run during the high gas loads. When the machine is off but under vacuum the 11 liter/second ion pump is sufficient to maintain system pressure.

CONCLUSION

We have demonstrated that a small inexpensive commercially available bulk sublimator can be very easily adapted to neutron generator operation. We have shown that the sublimator chamber can serve as the vacuum manifold and that passage of a beam of deuterons thru the sublimator chamber during sublimation does not interfere with generator operation. The addition of a small water-cooled ion pump completes the system and compliments the operation of the sublimator. The combined pumping system has the capacity to pump large quantities of deuterium and tritium, which are buried in the walls of the sublimation chamber. The sublimator/ion system eliminates initial pumpdown problems which are a common occurrence as the conventional getter-ion pump ages, and also allows the operator a wide choice of operating pressures. The advantages of a variable pump capacity can be seen clearly in the present tests. If it were not for the capacity of the sublimator we could not have run the accelerator under an air leak condition.

REFERENCES

1. R. Steinberg, and D. L. Alger, "A New Approach to the Small Accelerator Vacuum System," Vacuum (20) 12, 1971.

2. C. M. Turner, J. G. Marinuzzi, and G. W. Bennett, "Improvement of Hydrogen Pumping Characteristics of Penning Discharge Getter-Ion Pumps," IEEE Trans. Nucl, Sci., NS-14(3) 831, (June 1967).

3. J. D. Berger, E. E. Watson, and R. J. Cloutier, "Health Physics Aspects of Low Energy Accelerators," Conference on the Use of Small Accelerators for Teaching and Research, Oak Ridge, Tenn., 8-10 (April 1968).

4. D. J. Harra, and T. W. Snouse, "A New Radiant Heated Titanium Sublimator," to be presented at the Fifth International Vacuum Conference, Boston, Mass., 11-15 October 1971.

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150-KILOVOLT NEUTRON GENERATOR OF THE TYPE WIDELY USED IN RESEARCH AND PRODUCTION UTILIZING A 140-LITER/SEC ION PUMP

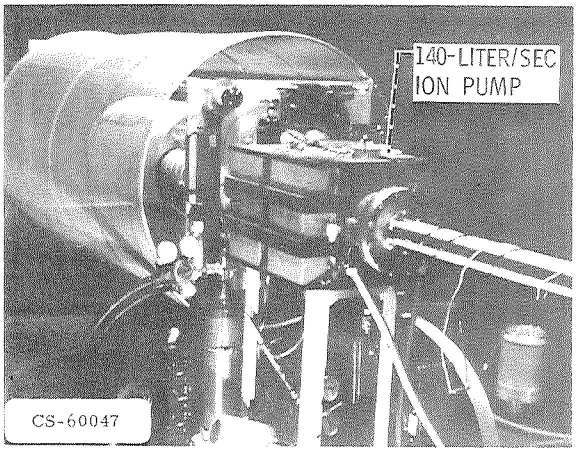

Figure 1

150-KILOVOLT NEUTRON GENERATOR WITH STANDARD ION PUMP REPLACED BY A SUBLIMATOR/ION PUMP PACKAGE

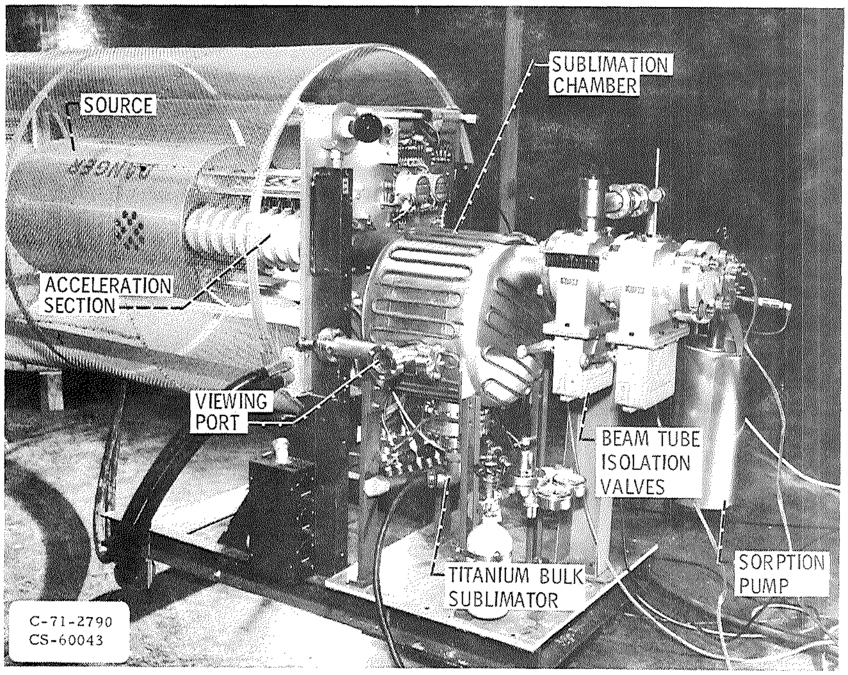

Figure 2

CLOSEUP VIEW OF THE WATER-COOLED SUBLIMATION CHAMBER, SUBLIMATOR, AND 11 LITER/SECOND ION PUMP

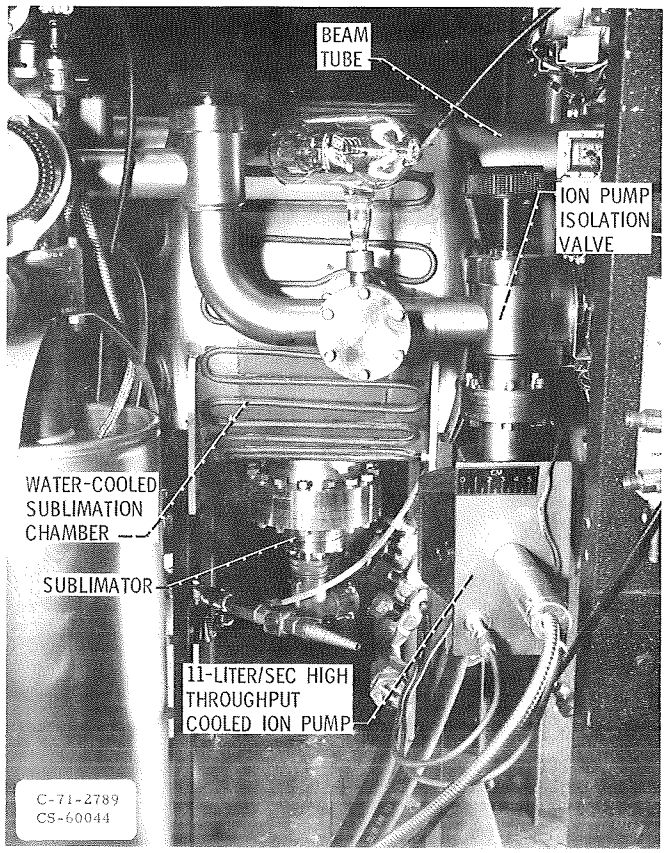

Figure 3

HEAD OF SUBLIMATION PUMP CONTAINING RESISTANCE HEATED HOLLOW TITANIUM SPHERE

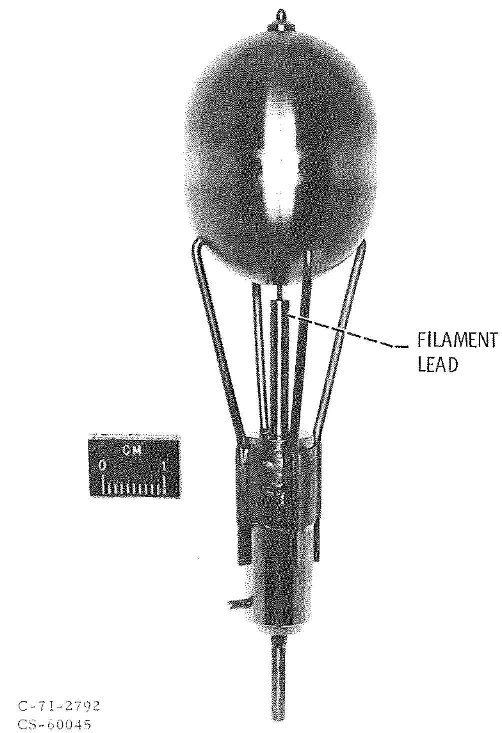

Figure 4

VIEW THROUGH SIDE PORT OF THE HOLLOW TITANIUM SPHERE
AT 1500^{0} C AND SUBLIMING AT 0.5 g/HR (4×10^{-7} TORR)

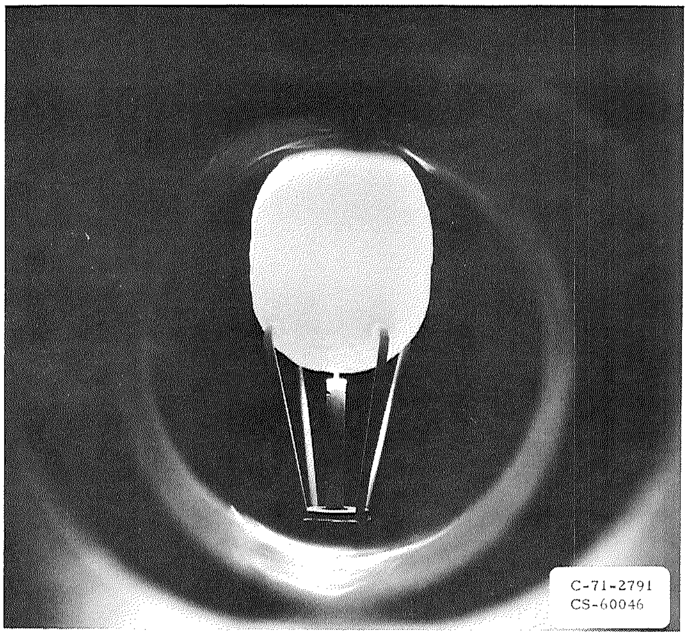

Figure 5

TYPICAL PUMPDOWN CYCLE FOR 150-KILOVOLT NEUTRON GENERATOR USING
2 SORPTION PUMPS FOR ROUGHING DOWN AND AN 11-LITER ION PUMP AND SUBLIMATOR

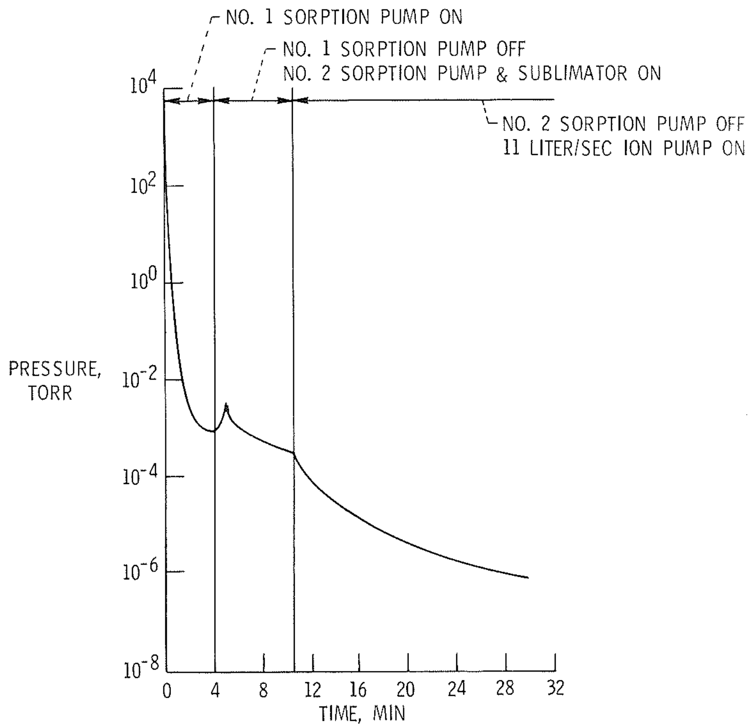

Figure 6

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TYPICAL PUMPDOWN AND OPERATING CYCLE FOR VACUUM SYSTEM OF 150-KILOVOLT NEUTRON GENERATOR FOR 2-DIFFERENT MODES OF OPERATION

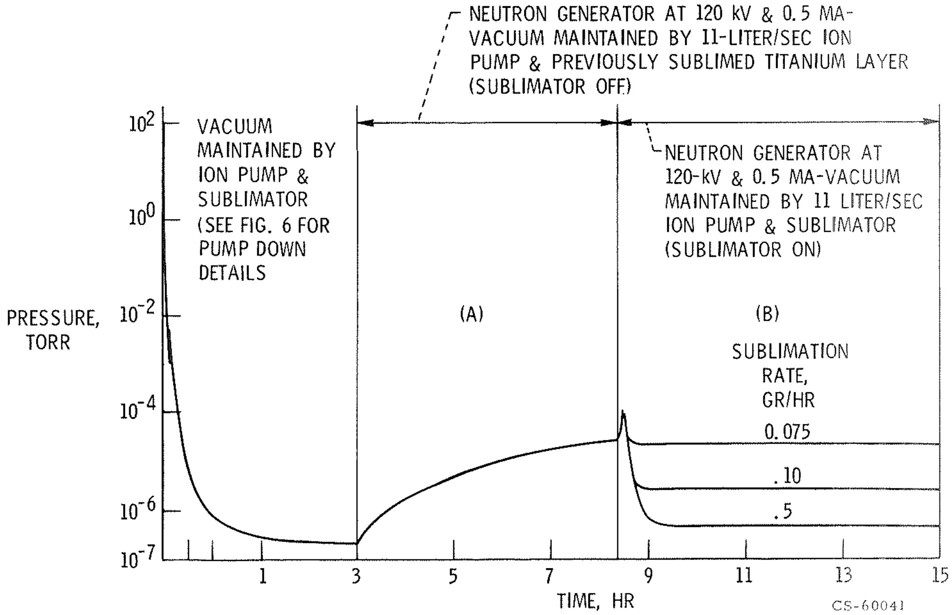

Figure 7